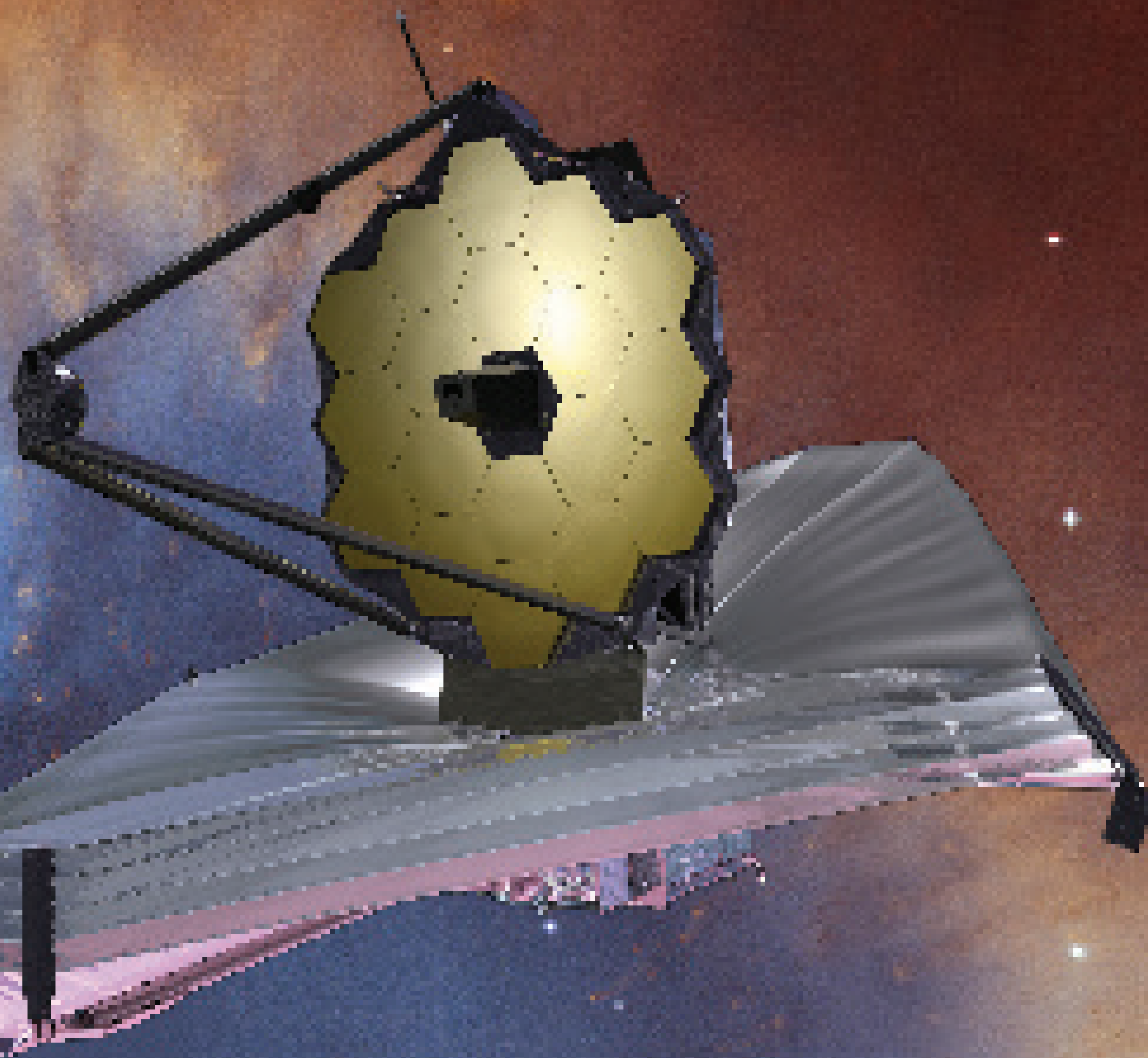
The James Webb Space Telescope

After many years the James Webb Space Telescope is well on its way to becoming a worthy successor to the Hubble Space Telescope.

By Jonathan P. Gardner and Heidi B. Hammel



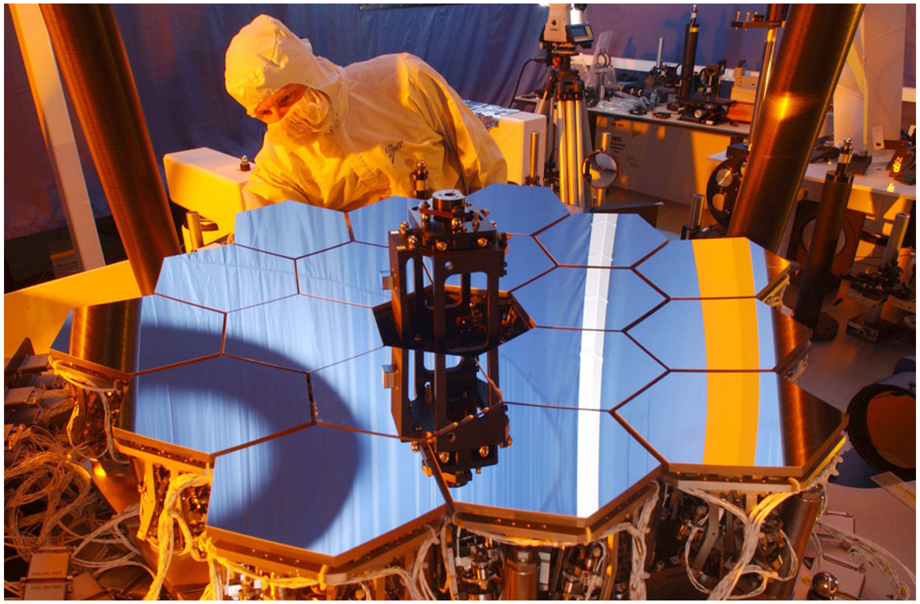
Artist's concept of the completed James Webb Space Telescope. Webb will be 100 times more powerful than the HST, and its science will range from studying cold objects in our own solar system to studying the first light that formed in the universe. Spacecraft illustration: NASA. Background (Helix Nebula): NASA, NOAO, ESA, the Hubble Helix Nebula Team, STScI, and NRAO.

TABLE OF CONTENTS

Editor's note: The ASP continues its inside look at the James Webb Space Telescope (JWST) with this Mercury *feature by two scientists who have been intimately involved in the project for many years. JWST Senior Project Scientist John Mather described the early history of the project in issue #110 of* Astronomy Beat*; he provides a detailed current status report on the project in* Astronomy Beat *#111 (May 14, 2013).*

Jonathan: I started working at NASA's Goddard Space Flight Center (GSFC) in 1996. I was excited about the upcoming installation of an infrared camera on the Hubble Space Telescope (HST) which I wanted to use to study galaxy evolution with deep surveys. Not long after I started work, I ran into one of my new colleagues, who told me about a new telescope that was going to be the successor to the Hubble — larger and optimized for the infrared. One of its main science goals was to do deep surveys for galaxy evolution. I realized right away that if NASA was going to build a space telescope designed for my research interests, then I needed to get involved! Fast-forward 16 years. The mission is the James Webb Space Telescope, currently under construction, and I am the Deputy Senior Project Scientist for the mission at Goddard.

Heidi: My experience with space telescopes literally started with a bang, when the fragments of Comet Shoemaker-Levy 9 plowed into Jupiter in 1994. I was head of the Hubble Team that imaged Jupiter in response to the impacts. I was pretty young, and had nothing to do with the creation of the HST, but I recognized that it was an incredible tool. Some years later, I was asked to participate in an *ad hoc* science working group to study a new type of space telescope. The telescope was later named for James Webb, the architect of NASA's Apollo Moon landings and also a staunch advocate for space science. I jumped at the chance to work on building a telescope for the next generation of young scientists, and a few years later I was



Top: A fully functional, 1/6th scale model of the Webb mirror in an optics test bed. *[Ball Aerospace]*
Above: Webb's mirror segments are made of beryllium and coated with gold. In this photo, engineers are using flashlights to inspect a mirror segment after shipment to Goddard. *[NASA/Chris Gunn]*

TABLE OF CONTENTS

Right: Webb's primary mirror segments will be installed on the backplane using a robot arm. The arm was used recently to test the procedures by installing a model mirror onto a model backplane. *[NASA/Chris Gunn]*
Far right: Webb's Mid-Infrared Instrument (MIRI) will do both imaging and spectroscopy at long wavelengths in the infrared. Here contamination control engineers conduct a "receiving inspection" of MIRI in the giant clean room at NASA's Goddard Space Flight Center. *[NASA/Chris Gunn]*

officially selected to be one of the six Interdisciplinary Scientists for the program. That was more than a decade ago, so it has been a pretty long, strange trip.

Mirror, Mirror

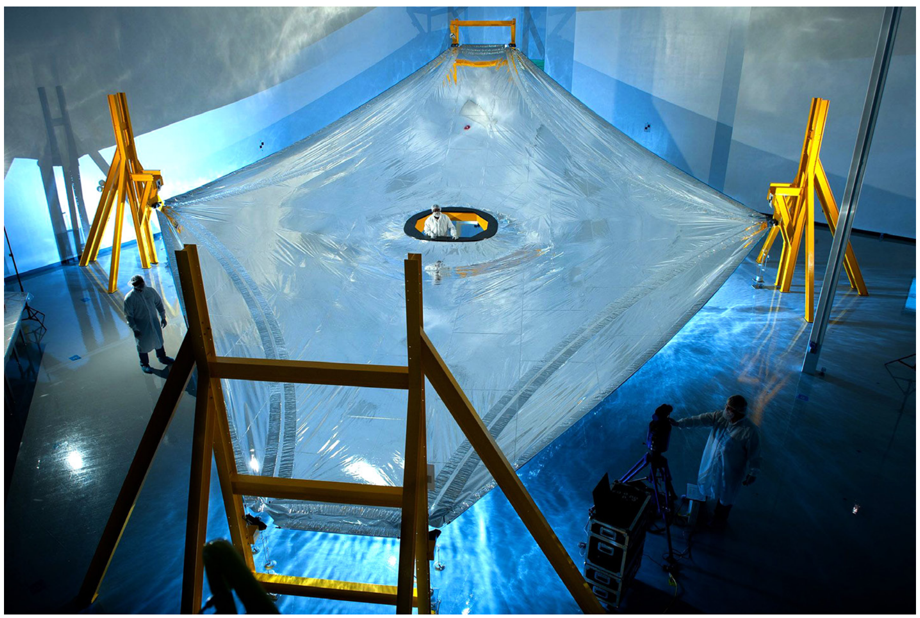
Jonathan: A telescope requires mirrors, and the good news about Webb's mirrors is that they are all finished. The primary mirror consists of 18 segments, each made of beryllium and coated with a microscopically thin layer of gold. Beryllium was selected because of its very stable thermal properties, and the coating is gold because that has the best reflective properties in the infrared. The gold coating is so thin that it comes to a little more than the mass of a dime for each mirror segment. All 18 mirrors work together as a single optical surface and are adjustable. The back of each mirror segment is supported with actuators, mechanisms arranged so that we can move the segment in many different ways. There is an additional actuator that pokes the middle of the mirror segment to adjust its curvature. We plan to re-align the mirrors every two weeks through the lifetime of the mission.

Heidi: Most of the primary mirror segments are still at Ball Aerospace in Colorado where they were made, but several have been shipped to the Goddard Space Flight Center. The mirrors will be installed onto the main framework of the telescope using a robotic arm on a huge structure called the Ambient Optical Assembly Stand (AOAS). The AOAS is 100,000 kilograms of welded steel built within the largest class-10,000 clean room in the world at Goddard. (A class-10,000 clean room has less than 10,000 particles larger than 0.5 micrometers per cubic foot. In comparison, normal room air has one million particles, so a class-10,000 clean room is 100 times cleaner than a normal room.) Goddard's clean room has a webcam

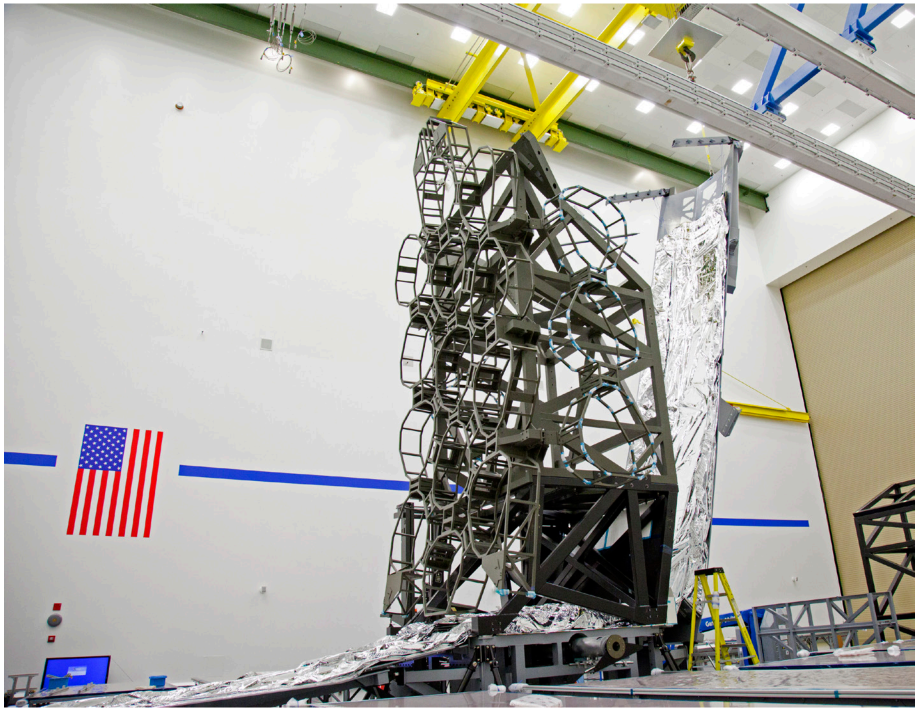
TABLE OF CONTENTS

which updates live images of the activity every 60 seconds, so you can watch Webb being built.

Jonathan: To see the first galaxies that formed in the early universe, we need to go fainter than Hubble can and see further into the infrared. So Webb's mirror is larger than Hubble's — 6.5 meters in diameter compared to Hubble's 2.4 meters — and it will be cold, operating near 50 kelvin or -370°F. To keep the temperatures down, the Webb telescope itself will be shielded from sunlight by a multi-layer sunshield the size of a tennis court. The sunshield consists of five layers of Kapton, a flexible plastic material. Heat escapes between each of the five layers (each about one foot away from the next), so every layer is colder than the next. If we wanted to give the "Sun Protection Factor" of Webb's sunshield, it would have an SPF of 1,000,000!



The Webb telescope project is developing a series of template sunshields with successively higher fidelity. This full-scale sunshield membrane is arranged on a test fixture to test its three dimensional shape. *[Northrop Grumman Aerospace Systems]*



The sunshield will be launched wrapped around the telescope. This picture shows the first of five template sunshield layers installed on a mock-up of the telescope back plane (a full-scale structural facsimile of the real observatory) to test the deployment sequence. *[Northrop Grumman]*

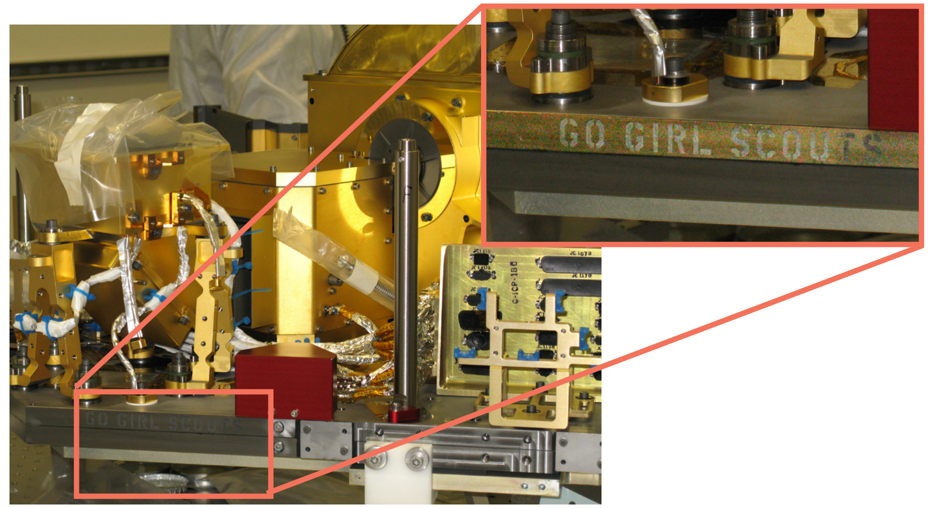
Instrumentation

Heidi: Webb will have four main science instruments, a mix of imaging systems and spectrographs. The imagers will provide amazing pictures, just like Hubble. The spectrographs will allow us to analyze the light from distant planets, stars, and galaxies to determine their chemical make-up, temperatures, pressures, distances, and many other properties. Two of the instruments are already at Goddard. The Mid-Infrared Instrument (MIRI, pictured on the previous page), which has a mixture of imaging and spectrographic capabilities, arrived from Europe last year. Soon after, the Canadian Space Agency delivered the Fine Guidance Sensor, which also has a Near-Infrared

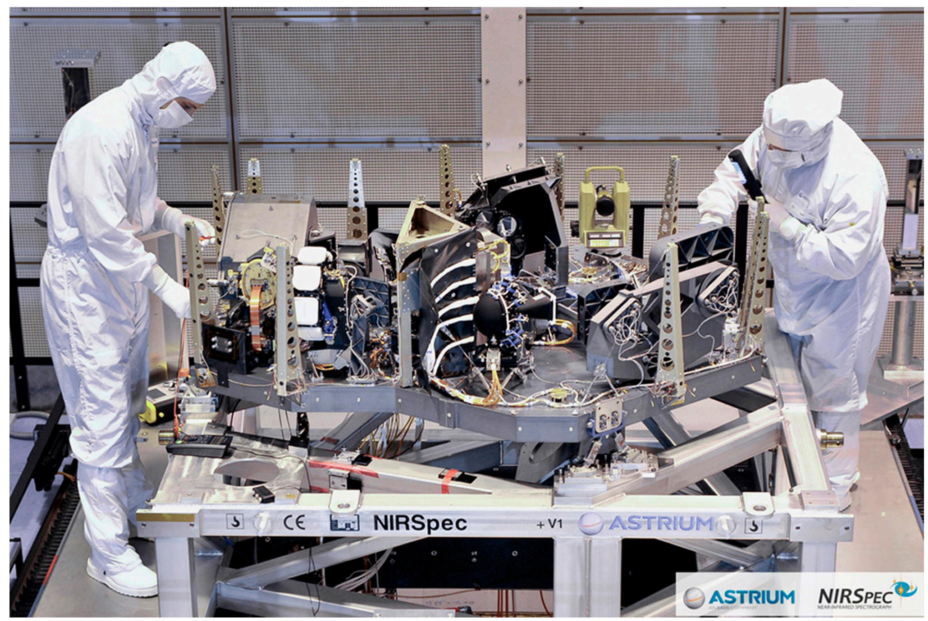
TABLE OF CONTENTS

Imager and Slitless Spectrograph sub-system (FGS/NIRISS).

Jonathan: The remaining two instruments should be completed this year. The main camera will be the Near-Infrared Camera, or NIRCam. The European Space Agency, in addition to providing the Ariane V rocket on which Webb will launch, also contributed a Near-Infrared Spectrograph (NIRSpec).

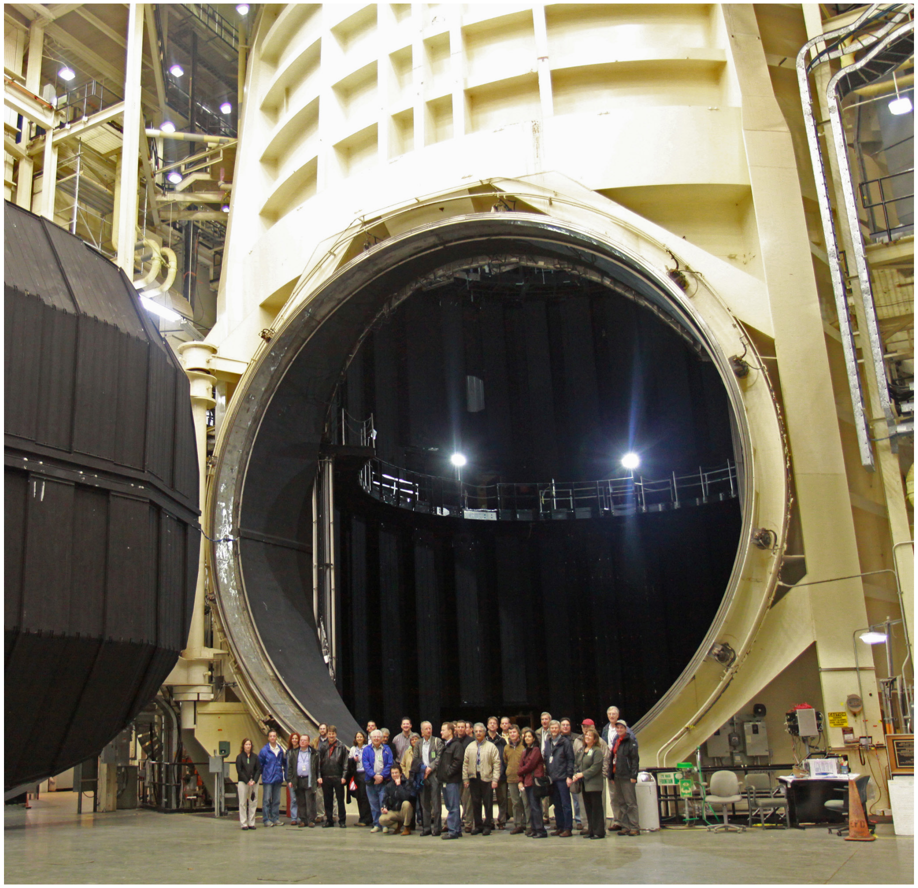


Above: NIRCam's flight modules are now fully assembled and are undergoing testing. One edge of the NIRCam camera is engraved permanently with "Go Girl Scouts" to honor the close partnership between NASA and Girl Scouts to encourage young women in science, technology, engineering, and mathematics. Visit this website if you'd like to learn more about NIRCam's education and outreach with the Girl Scouts. *[NIRCam Team, University of Arizona]*



Above: Webb's Fine Guidance Sensor and Near-Infrared Imager and Slitless Spectrograph (FGS/NIRISS) was built by the Canadian Space Agency and recently delivered to NASA's Goddard Space Flight Center. In this image, the instrument is being lifted for placement on a master tool for key measurements prior to installation onto its flight structure. *[NASA Goddard/Chris Gunn]*
Right: Webb's Near-Infrared Spectrograph, seen here undergoing testing, was contributed by the European Space Agency. *[Astrium/NIRSpec]*

TABLE OF CONTENTS



Jonathan Gardner joins some members of the Webb team in front of the giant vacuum chamber known as Chamber A at the Johnson Space Center. Built for the Apollo program in the 1960s, Chamber A is 12 meters in diameter and 35 meters high. The Webb project team added an extra inner shroud that will use gaseous helium to cool the chamber to below liquid nitrogen temperatures. *[Jonathan Gardner]*

On to Launch

Heidi: Since both the primary mirror and the sunshield are larger than the Ariane 5 rocket's five-meter-diameter cargo area, they will be folded up and stowed for launch. Unfurling the sunshield just after launch will be one of the most exciting parts of the mission.

The ivory-colored semi-cylindrical aluminum trailer will be used to move components of the telescope within the US and transport the telescope to French Guyana. The trailer measures 18.5-feet wide by 17-feet tall. *[NASA/Desiree Stover]*

The sunshield will be folded within protective covers for launch, with the covers folded around the telescope. After launch, the covers will be unfolded and then opened. The sunshield will then be drawn out of its covers with a series of pulleys. The final step will separate the five layers. We are building a series of test pieces, each more flight-like than the last, to allow us to optimize the shape of the covers and sunshield, and to determine the best way to fold it up and practice unfolding it.

Jonathan: Webb will be launched in 2018. Although we have many of the pieces nearly complete, the big task of putting it all together remains; we call this process "integration." We also need to make sure it is all going to work when it gets into orbit. That means a lot of testing. The instruments will be tested at Goddard while the mirror is being assembled in the clean room. But to test

TABLE OF CONTENTS

them together, we have to use a giant vacuum chamber at the Johnson Space Center. The full end-to-end optical test of the telescope and instruments together on the ground will ensure that it all works correctly after launch.

Heidi: This telescope is big, and so shipping it around the country is not trivial. Its penultimate trip will be from the US to the launch pad in French Guyana. NASA has built a giant transport carrier to keep the telescope safe during its travels.

Jonathan: Like Hubble, Webb is a general-purpose observatory and will address nearly every aspect of astronomy. Much of the amazing science to come from Webb will be things that we — the scientists who are helping to building this incredible machine — have not even thought of yet. One of the most important lessons we learned from Hubble was to expect the unexpected: fully half of the most amazing results were never even considered when Hubble was being built. Therefore, each year scientists from around the world will submit proposals to use Webb and a review committee will select the best ideas. We expect a lot of competition among scientists to use this powerful telescope. Hubble is awesome, and Webb will be better.

Heidi. Better than awesome? That's NASA!

The full-scale model was assembled on the lawn at Goddard Space Flight Center in Greenbelt, Maryland, and displayed during September 19-25, 2005. The Webb Telescope team took a group photo with it; seeing people gathered next to it reveals its scale. *[NASA]*

HEIDI B. HAMMEL is a planetary astronomer and one of the six Interdisciplinary Scientists for the James Webb Space Telescope. She is currently the executive Vice President of the Association of Universities for Research in Astronomy (AURA, Inc.) in Washington DC. Heidi is best known for using the Hubble Space Telescope to study giant planets and impacts on Jupiter, as well as for her award-winning public outreach.

JONATHAN P. GARDNER is the Chief of the Observational Cosmology Laboratory and the Deputy Senior Project Scientist for the James Webb Space Telescope at NASA's Goddard Space Flight Center. He studies galaxy evolution using the Hubble Ultra-Deep Field and other galaxy surveys and looks forward to the day when Webb will find the first galaxies that formed in the early universe.

TABLE OF CONTENTS